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ABSTRACT

This study tested the effectiveness of having fifth-grade students generate their own examples of selected concepts on energy. Hypotheses were that subjects would perform better on sections of a test related to definitions and recognition of exemplars of the concepts for which they found their own examples than on sections related to comparible science concepts for which they did not generate examples. Subjects were 26 fifth-grade students enrolled in a university laboratory school. During the 3-week unit on energy, students generated their own examples of 13 energy concepts being studied. Results confirm the hypothesis that elementary school science students recall concepts for which they generate their own examples better than concepts for which they do not. Apparently, the process of finding and recording examples of concepts, and the attendant thinking about the concepts while seeking adequate examples, strengthens knowledge of the concepts themselves more than simply adding further examples of the concepts to the children's long term memory. (MVL)

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# Effects of Self-Generated Examples on Elementary School Students' Retention of Science Concepts

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# Effects of Self-Generated Examples on Elementary School Students' Retention of Science Concepts

Examples of concepts function as mediating elements in the learning and application of conceptual knowledge (Medin & Schaffer, 1978; Tennyson & Cocchiarella, 1986). This mediating function derives from the elaborative nature of concept examples, which provide additional information to enrich the learner's schema associated with the concept (DiVesta & Peverly, 1984; Tennyson & Park, 1980). If the learner stores information concerning a concept's defining characteristics in terms of particular examples that have been presented formally or informally, the retention of appropriate exemplars provides meaningful elaborations related to the targeted concept.

It has been suggested that memories of specific examples may form prominent parts of people's representations of concepts (Medin & Schaffer, 1978). Comparison of a new object to an already known example of that type of object enables the individual to classify that object as an example of the concept. Additionally, the use of representative examples as mental guides allows individuals to infer the necessary conditions for an instance of a particular concept to occur when engaged in formal or informal learning. The learning of a concept, from this perspective, would hinge upon being presented with accurate and salient exemplars from the onset, and should lead to more accurate recognition of appropriate exemplars encountered later. For instance, Kossan's (1981) study of 7 and 10 year olds found that the younger children learned concepts more effectively when they paid close attention to particular instances than when presented with classification rules; for 10-year-olds, rule-based and exemplar-based learning were equally effective.

While the exemplar-based approach to understanding concept learning has certain attractive features, it has been pointed out that conceptual representations are more likely to be composed of more than examples (Siegler, 1986). Learners most probably link examples with some form of propositional representation, using each as supportive information for the other in the learning of a concept. The notion that there are reciprocal associations between the storing of a rule or proposition and the storing of examples of that rule or proposition supports the idea that generating examples will strengthen the acquisition of concepts.

In addition to the presumed relationships between rules and examples, elaborations upon concepts that are being acquired improve retention and retrieval by providing alternative paths for accessing the information and by providing extra information upon which one may form representations later (Anderson, 1985; Gagne, 1985; Hyde & Jenkins, 1973). It has been shown in several learning contexts that self-generated elaborations lead to better retention (Bobrow & Bower, 1969; Reese, 1977; Slamecka & Graf, 1978; Stein & Bransford, 1979) than not using elaborations or using elaborations provided by others. Additionally, retention and comprehension of textual information is improved when readers generate associations to the text as they read (Linden & Wittrock, 1981). The suggestive nature of studies on elaborations in various contexts raises the possibility that self-generated examples, those that have been found or invented by the learner, might provide the learner with meaningful elaborations. These self-generated examples may constitute extra, and potentially more personal, experiences with the concept and thus could lead to better retention of the concepts.

In addition to the elaborative nature of acquiring examples of concepts, evidence from research on conditions related to learning declarative knowledge suggests that deeper processing of information and variable contexts for processing information enhance the transfer of information. Deeper processing of concepts using semantic representations should enable a learner to retrieve information by means of more complex sets of associations (Bradshaw & Anderson, 1982; Craik & Tulving, 1975). The presentation of meaningful concepts by means of variable contexts during the acquisition phase leads the learner to being able to recognize broad applications of the concept (DiVesta & Peverly, 1984).

It seems likely that storing a variety of self-generated examples of concepts would entail deep processing by creating personal associations between the examples and the formal representation of the concept. Also, time spent in generating examples provides extra practice of the concepts, and eventual expansion of schemas because of the variable contexts related to the examples provided by the learner. Thus, these supportive processing features of providing one's own examples may contribute to later retrieval. Personal elaborations developed through associations with particular examples or prototypical examples, related to the concept as it is being learned and modified should provide additional structures for retrieving that concept in appropriate future contexts.

Of interest in this study is the role that self-generated examples of science concepts plays in children's retention of those concepts. A recent study using adult students (Gorrell & Downing, 1988) demonstrated that subjects performed better on a test of concepts for which they had generated their own examples than for concepts devoid of self-generated examples. The

current study was devised to extend the Gorrell and Downing study to elementary school students, thereby testing the effectiveness of having students generate their own examples of selected science concepts.

This study was conducted during a three-week unit on energy presented in a normal classroom. Since there is only on class at each grade level in the school, the setting did not allow for random assignment to treatment groups. Thus, a within-subjects design was chosen instead of a between-subjects design that could have tested the effects across groups. It was thought that an *in vivo* study of this nature would contribute more to the practical issues of science instruction than one that controlled variables fully in exchange for creating an artificial learning environment (the laboratory) which would lose the sense of a real classroom.

Hypotheses were that subjects would perform better on sections of a test related to definitions and recognition of exemplars of the concepts for which they found their own examples than on sections related to comparable science concepts for which they did not generate examples.

## Method

### Subjects

Subjects were 26 fifth grade students enrolled in a university laboratory school. The school maintains a representative sample of socioeconomic class and ethnicity of the community in which it resides. Females constituted 46% and males constituted 54% of the students in the class.

### Instruments

Instruments were multiple choice examinations that tested for retention and understanding of 26 major concepts related to energy, which were listed in the vocabulary section of the science textbook in which the students read. For

each concept there were two multiple choice questions: one testing for the students' knowledge of the definition or meaning of the concept and one testing the students' ability to recognize appropriate exemplars of the concept.

Procedure

Prior to the introduction of the experiment in the class, students were given a pretest containing all of the concepts they were about to learn in a three-week unit on energy. Item analysis of the pretest enabled the researchers to construct a list of all the concepts in order of difficulty. From this list, items of comparable difficulty were paired. One item from each pairing was selected to be among those in the treatment condition (generation of examples) and the other was selected to be in the control condition (no generation of examples). Both lists of concepts may be found in Appendix A.

A worksheet that listed each of the concepts for which students were to find their own examples was constructed. This worksheet included an sample of how to record the example and instructions concerning what sources the student could use for generating an example (see Appendix B). In addition, the consent form sent to parents detailed the basic expectations of the assignment, explaining that the family members were allowed to help the child generate examples but disallowing the copying of examples from textbooks or reference books. Students were instructed to rely as much as they could upon their own observations and thinking in generating examples to be turned in.

The unit on energy was taught in the teacher's usual fashion, employing a variety of individual, small-group, and full-class activities. The completed assignment was submitted to the teacher at the conclusion of the unit.

Students completed the posttest at that time. In addition, two weeks following the completion of the unit, a trained research assistant, a woman in her thirties, conducted structured interviews with each student, in which she explored the methods the students used to complete the assignment. The interviewer asked the following questions:

1. When you had to find examples for your science class, how did you do it?
2. How did your family (parents, brother, sister) help you?
3. Give an example of how you figured out an example for the assignment.
4. What was the most interesting part of the assignment?
5. What was the hardest part of the assignment?
6. What was the easiest part of the assignment?
7. Is there anything else you would like to say about the assignment?

Responses to these questions were recorded and transcribed for later inspection in order to gain qualitative information concerning the students' means of completing the assignments.

## Results

A 2 (pretest vs. posttest) x 2 (generated vs. non-generated examples) x 2 (multiple-choice definitions vs. exemplars) repeated measures ANOVA was employed to test the hypotheses. From this within-subjects analysis, statistically significant main effects for posttest performance on both the exemplars section, $F(1,24) = 28.44$, $p < .001$, and the definitions section, $F(1,24) = 62.19$, $p < .001$, were obtained. Mean increases in number of items correct were 6.56 and 6.84,

respectively. Table 1 shows the means and standard deviations for each subtest.

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Insert Table 1 about here

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There was no statistically significant overall effect for the treatment condition (generated examples) versus the control condition (non-generated examples), but there was a statistically significant effect for the treatment and control conditions related to the definitions section of the test, $F(1,24) = 12.28$, $p < .002$. Subjects performed better on the section of the test related to definitions of concepts for which they had found examples than on the section related to definitions for which they had not found examples. The means of the two groups were 9.76 and 8.48, respectively. The effect size for this difference was .55. Figure 1 shows the pretest and posttest scores on each section of the test.

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Insert Figure 1 about here

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Interviews with the students indicate that in general they did find their own examples for each concept, but that they obtained permissible help from their family relatively frequently. Four general strategies for fulfilling the assignment were cited by the students: looking up the

concept in a book (text, reference, or other science book), then seeking an example based upon the definition or explanation (12 students); referring to the assignment sheet while looking around the house for examples (16 students); asking a parent (usually the mother) or other family member for help in finding examples, which was sometimes combined with looking the concept up in a book (20 students); and using an example from the textbook, often modifying the example to fit the student's own experience (10 students). Since each student could have employed each of the four main strategies, the number of strategies used adds to much more than the number of students involved.

An interesting element of the interview process were many of the responses given when the students were asked to provide an instance of how they found examples. Several of the students comments demonstrate that their understanding of the concepts are linked strongly to the occasion when they found an acceptable example. A few salient examples of students explaining how they derived an example and how that example fits the concept are listed below:

— I read in the book about what kinetic energy meant. I looked around the house and remembered that we had fish. I looked in there and checked to see if the fish were moving at that very moment. They were, so I wrote, "Fish have kinetic energy when they are moving."

— There was one for conduction and when you have a pot and you're boiling water and it's real hot and it goes up into the pot's handle — I found an example of that. I looked in the back of the book that has all the definitions. I found the definition for that word

and when I saw that it meant something like that, I thought of pots and pans.

— For kinetic energy, I put a ceiling fan because the things go round — the blades go. I was in my mom and dad's bedroom and we have one in there and so I was just thinking, "How about a ceiling fan; it moves." So I said, "Yeah."

— Potential energy. It was how you can save energy like turn off the lights when you come out of your room. I looked potential energy up in the dictionary and I found that it was to save energy. I just thought to save energy, turn off the lights when you finish — not to leave them on.

— Like trying to explain how a light bulb would work. You have energy that's transferred from one thing to another — like an energy change-out. Water changes to ice. I found some stuff in books and different things from reading about energy change and energy resources and things.

— Electrical energy. It was from the socket where you plug in something and as soon as it gets electrical energy to the wire, it gets to the thing you plug in.

## Discussion

Results confirm the hypothesis that elementary school science students recall concepts for which they generate their own examples better than concepts for which they do not. That the effect was found for definitions of concepts and not for exemplars of the concepts is interesting. Apparently, the process of finding and recording examples

of concepts, and the attendant thinking about the concepts while seeking adequate examples, strengthens knowledge of the concepts themselves more that simply adding further examples of the concepts to the children's long term memory.

This finding is of interest to those concerned with the role of examples in learning and the subsequent storage of acquired examples. The current study provides evidence that experiences that tie the learning of concepts to examples generated by the learner may support the overall retention and understanding of the concepts in question.

A limit of the general finding is that there were no controls for amount of time devoted to the learning or manipulation of the concepts. Thus, those concepts that were not on the list for finding examples were probably paid less attention. The fact that students remember the definitions of those concepts associated with the assignment more frequently than those not assigned could be due to the extra amount of practice involved in any type of manipulation of the concepts mentally. However, the active nature of seeking one's own examples does introduce a level of interaction with concepts that is not achieved with the usual assignment that requires simple copying from other sources.

Working against the possibility of finding a treatment effect was the fact that students could actually depend heavily on the ideas of others, including others in their classroom, when completing the assignment. Merely copying the answers of another does not coincide with the experimenters' ideas of self-generated examples, and there was concern that whatever effects that potentially would exist would be watered down by the extraneous variables associated with carrying an assignment sheet

around for three weeks. Considering that the conditions under which these subjects completed their assignments contained several problems that decreased the chances of finding a statistically significant effect, the findings are even more impressive.

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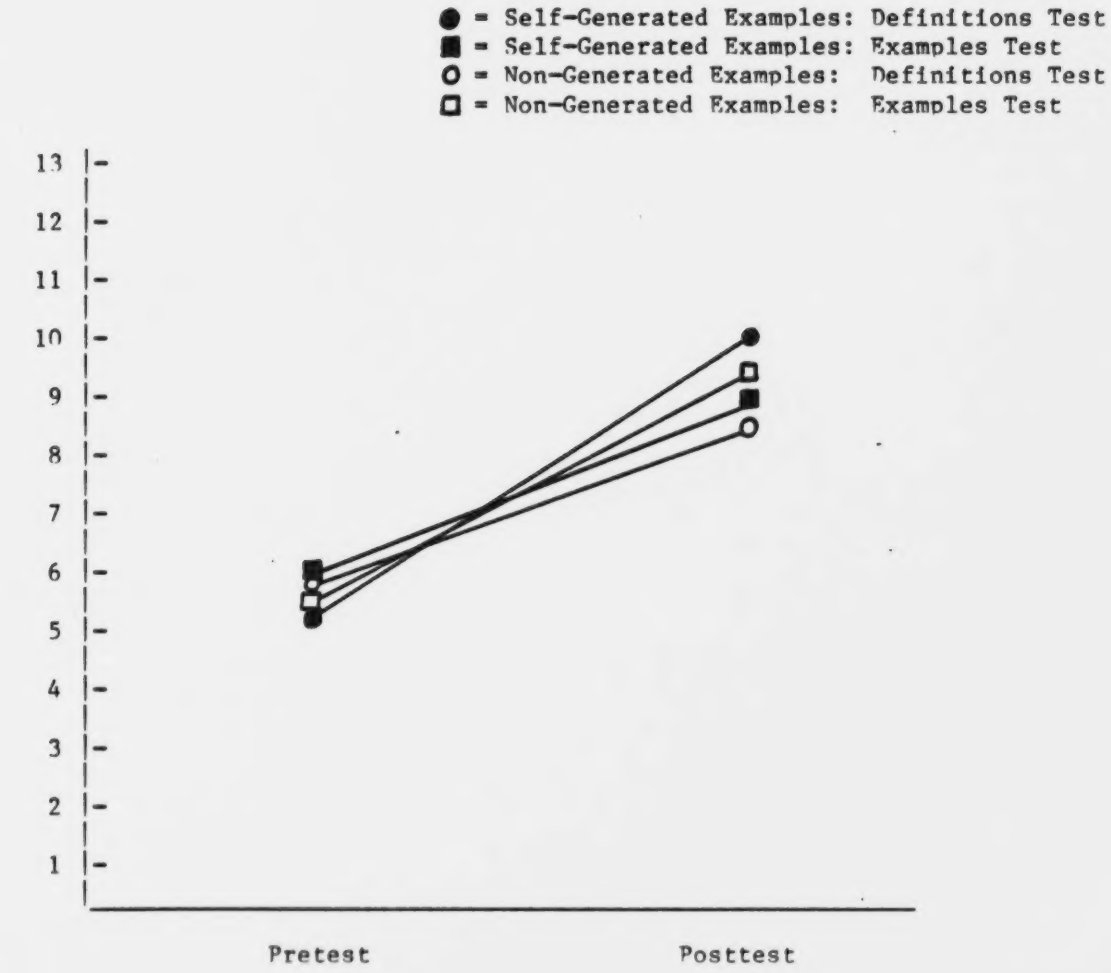
Table 1

Means and Standard Deviations for Each Section of the Pretest and Posttest.

| | Type of Subtest | | | |
|---|---|---|---|---|
| | Definitions | | Examples | |
| Concept Type | Self-Generated | Non-Generated | Self-Generated | Non-Generated |
| Pretest | | | | |
| X | 6.00 | 6.46 | 6.63 | 6.38 |
| SD | 3.55 | 3.09 | 3.21 | 4.07 |
| Posttest | | | | |
| X | 9.63 | 7.92 | 8.92 | 9.08 |
| SD | 2.87 | 2.00 | 2.95 | 2.28 |

Note: Maximum score for each subtest is 13.

Figure 1. Means for Each Sub-Test on Pretests and Posttests.



## Appendix A: Lists of Concepts Used in the Study

### Concepts Included in the Self-Generated Examples List

1. kinetic energy
2. potential energy
3. energy of position
4. chemical energy
5. solar energy
6. x-ray
7. radar
8. energy source
9. conduction
10. convection
11. conserving
12. thermostat
13. appliances

### Concepts in the Control List

1. energy
2. mechanical energy
3. electric energy
4. heat energy
5. radiant energy
6. light energy
7. energy receiver
8. energy transfer
9. radiation
10. energy chain
11. fuels.
12. insulation
13. petroleum

Appendix B: Sample Instruction Sheet

Science — Energy Unit: 5th Grade

Name _____

Listed below are some science words in our Energy Unit. Find an example of each one at home with your mom or dad and explain why it is an example. Write it next to the word. You will see an example of how to complete this sheet in the space below.

| Science Word | Example I found at home |
|---|---|
| energy | When my dad takes out the garbage, he is doing work by moving an object, so he is using energy. |

| Science Word | Example I found at home |
|---|---|
| 1. kinetic energy | |